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DETECTION DEVICE COMPRISING A PARABOLIC MIRROR AND USE OF SAID DEVICE IN AN OVERFLIGHT MACHINE

The present invention relates to a detection device
5   with parabolic mirror. It relates in particular to such
a device having operation of radar type, in particular
operation of the synthetic aperture radar, or SAR
standing for "Synthesized Aperture Radar", type.

10   Detection devices with parabolic mirror are commonly
used to search for the presence of particular objects
in a determined geographical zone. The objects searched
for may, for example, be metal parts or heat sources.
The detection device is then stowed on board an
15   aircraft or a satellite which overflies the
geographical zone concerned.

The geographical zone may be traversed according to a
scan corresponding to the displacement of the
20   overflight machine. This displacement defines a band in
the geographical zone, called a sweep, which possesses
a ground width, along a direction perpendicular to the
displacement of the machine, and determined by the
characteristics of the detection device and by the
25   altitude of the machine. The direction of displacement
of the overflight machine is commonly called the
azimuth, and the direction perpendicular to the
displacement is commonly called the elevation, or else
distance. A width of sweep which is all the larger
30   makes it possible to reduce the number of passes of the
machine above the geographical zone, that are necessary
in order to fully cover the latter with mutually
adjacent sweeps.

35   To increase the width of sweep, certain known detection
devices make it possible to vary the elevation of the
direction of detection between several determined
values. Each direction of detection thus adopted

corresponds to a secondary ground band, situated inside the sweep and called a sub-sweep. The width of the sweep then corresponds to the sum of the widths of the sub-sweeps. A greater sweep width may thus be obtained.
5   By way of example, a sweep width of greater than 400 kilometers is achievable using 5 sub-sweeps. A mode of operation of an SAR device which allows scanning with several sub-sweeps is called "ScanSAR", standing for "Scanning Synthesized Aperture Radar".
10

Among the known detection devices which allow detection in several directions, may be mentioned the electronic scanning antennas, also called "Active Antennas". An active antenna is constituted by a matrix of detectors
15   and a control system linked to each of the detectors. The control system combines elementary reception signals delivered by all the detectors, applying a phase shift associated with the position of the corresponding detector in the matrix to each elementary
20   signal. The whole set of phase shifts used defines the direction of detection. An identical principle is used for a matrix of radar transmitters, to obtain a radiation emission focused in a determined direction. Devices with active antennas exhibit very good
25   performance, but their complexity and their cost constitute significant drawbacks.

Other detection devices are known, which incorporate a parabolic mirror and a detector placed at the focus of
30   this mirror. These devices are much simpler, and consequently less expensive than the previous ones. In a device with parabolic mirror, the direction of detection is determined by the orientation of the mirror. This orientation may be modified either by a
35   movement of the mirror with respect to the machine on board which the detection device is stowed, or by a roll movement of the machine itself during its displacement. In both cases, the direction of detection

varies relatively slowly. Therefore, such a device is not suitably adapted for carrying out a scan of a geographical zone with several sub-sweeps.

5   It is also known to place an active antenna of reduced dimensions in the focal plane of a parabolic mirror, at the level of the focus of the mirror. The operation and the characteristics of such hybrid detection device result from a combination of the respective manners of

10 operation and characteristics of the active antenna and of the parabolic mirror. In particular, phase shifts are again introduced between several detectors/transmitters of the active antenna which are simultaneously activated to obtain a determined

15 direction of detection. However, such hybrid devices are again complex and expensive.

An object of the present invention is to propose a simple and inexpensive detection device which makes it

20 possible to effectively scan a geographical zone with several sub-sweeps.

To this end, the invention proposes a detection device comprising a parabolic mirror and several radiation detectors placed in a focal plane of the mirror. The

25 focal plane is substantially perpendicular to an axis of the mirror and contains a focus of the latter. The detectors are positioned with respective offsets along a determined common direction parallel to the focal

30 plane. The detection device furthermore comprises a selection system connected to each of the detectors and devised so as to successively select just one of the detectors and to transmit a reception signal originating from the selected detector. The respective

35 offsets of the detectors in the focal plane of the mirror are chosen so that a reception gain diagram of said device exhibits, between two successive gain maxima in said diagram and corresponding respectively

to one of the detectors, a gain minimum of less than
3.0 dB below each of said gain maxima.

In a detection device according to the invention,
5 various directions of detection are obtained by virtue
of the use of several detectors in combination with a
parabolic mirror. The radiation received along each of
these directions is focused onto one of the detectors
by reflection off the mirror. Changes of direction of
10 detection are obtained by means of the detector
selection system. Rapid changes of direction of
detection may thus be obtained, in particular
electronically, which make it possible to carry out an
elevation-wise scan of an explored geographical zone.
15 By virtue of the choice adopted for the offsets, the
scan obtained comprises sub-sweeps parallel to the
displacement of the detection device which are
juxtaposed pairwise. No detectionless band separates
two adjacent sub-sweeps: continuous detection may be
20 performed over the whole width of the sweep.

It is specified that the selection system for a
detection device according to the invention may be
particularly simple, and hence inexpensive.
25 Specifically, this selection system is designed so that
only one of the detectors situated in the focal plane
of the mirror is activated at each instant. The other
detectors are then deactivated. The direction of
detection is therefore fixed uniquely by the selection
30 of the single activated detector, without introducing
phase shifts between signals of several detectors.

An advantage of a detection device according to the
invention results from the reduced number of detectors
35 necessary. By way of example, a detection device
according to the invention can comprise four or five
detectors. This results in a significant reduction in
the cost of the detection device relative to an active

antenna, as well as a decrease in the weight of the device.

In a preferred manner, the respective offsets of the
5 detectors in the focal plane of the mirror are chosen
so that the gain minimum, situated between two
successive gain maxima in said diagram and
corresponding respectively to one of the detectors, is
less than 1.5 dB below each of said gain maxima. An
10 almost uniform detection sensitivity is thus obtained
over the width of the sweep.

Optionally, the detectors may be disposed in an aligned
manner in the focal plane of the parabolic mirror. A
15 particularly simple mounting of the detectors in the
focal plane results therefrom.

Furthermore, the detector selection system may be
simplified, by virtue of the reduced number of
20 detectors used. It may be adapted to select the
detectors in a cyclic manner. A periodic transverse (or
elevation-wise) scan of the sweep is thus obtained,
which is distributed in a balanced manner between the
sub-sweeps.
25

The selection system may also be adapted for selecting
the detectors in an increasing or decreasing order of
the respective offsets of the detectors in the focal
plane of the mirror. A progressive transverse (or
30 elevation-wise) scan of the sweep is thus obtained,
passing successively from a given sub-sweep to an
adjacent sub-sweep. The detection device is then
compatible with commercially available software for
reconstructing the geographical zone explored.
35

According to the preferred embodiment of the invention,
the detection device is adapted to operate for radar.
To do this, each detector is adapted to operate for

emission or reception of radiation. Such a detector is
then commonly called a source. The selection system is
then devised so as to furthermore transmit an emission
signal to the selected detector. More particularly, the
5   detection device may be specifically adapted to operate
for synthetic aperture radar.

In the case of radar operation, the detection system
may have the following particularly simple structure.
10   It may comprise several branches each connected to an
input and to an output of the selection system, each
detector being connected to one of the branches. Each
branch comprises selectors disposed at nodes of said
branch. Each selector is devised so as to reproduce an
15   emission signal intended for one of the detectors on an
output of said selector, selected as a function of an
emission selection signal transmitted on a control
input of said selector, then so as to reproduce a
reception signal originating from said detector and
20   transmitted on an input of said selector, selected as a
function of a reception selection signal transmitted on
the control input of said selector.

The invention also relates to a use of a detection
25   device as described above on board a machine for
overflying a geographical zone in which the detection
is effected. The selection of the detectors then forms
a complete scan of a sweep of said zone in combination
with the displacement of the overflight machine. The
30   expression a complete scan of a sweep is understood to
mean a scan in which the ground fields covered
successively for one and the same direction of
detection, that is to say the successive fields
belonging to one and the same sub-sweep, are adjoining
35   or mutually overlapping in the azimuth direction. A
sub-sweep is then completely covered during a single
pass of the overflight machine. Preferably, the
detection device is oriented in such a way that the

direction of offset of the detectors in the focal plane
of the parabolic mirror is substantially perpendicular
to the azimuth direction. A maximum sweep width is thus
obtained.

5

Other features and advantages of the present invention
will become apparent in the following description of
two nonlimiting exemplary embodiments, with reference
to the appended drawings, in which:

10

-     figure 1 is a perspective diagram of a detection
      device according to the invention;
-     figure 2 illustrates an exemplary disposition of
      the detectors for a detection device according to
15   figure 1, comprising four detectors;
-     figure 3 is a functional diagram of a detector
      selection system that can be used in a detection
      device according to figures 1 and 2;
-     figure 4 corresponds to figure 2 for a detection
20   device according to the invention comprising five
      detectors;
-     figure 5 is a functional diagram of a detector
      selection system that can be used in a detection
      device according to figure 4;
25 - figure 6 illustrates the principle of the
      selection of a detector according to the
      invention;
-     figure 7 illustrates a use of a detection device
      according to figures 1 to 3; and
30 - figures 8a and 8b are two gain diagrams for a
      detection device according to figures 1 to 3,
      corresponding to figure 7.

For the sake of clarity, the dimensions of the elements
35 represented in figures 1, 2 and 4 do not relate to
actual dimensions. Furthermore, identical references
used in several figures designate identical elements.

The invention is now described in detail within the framework of a synthetized aperture radar (SAR).

5   In accordance with figure 1, the parabolic mirror 1 corresponds to a part of a paraboloid of revolution referenced P, with axis Z'-Z and focus O. The mirror 1 corresponds to a substantially elliptical shape, inscribed within the surface area of the paraboloid P. The distance between the axis Z'-Z and the point A1 of

10   the periphery of the mirror 1 closest to this axis is called the guard diameter or "clearance". It is denoted C. D is the projected diameter of the mirror 1 between the point A1 and the point A2 of the periphery of the mirror 1 opposite A1. By way of example, C may be equal

15   to 20 cm and D may be equal to 1 meter. The mirror 1 consists of a material having a high electrical conductivity, such as aluminum, for example.

According to the known geometrical laws, a radiation R0

20   entering the paraboloid P parallel to the Z'-Z axis is reflected off the internal face of the latter and converges to the focus O. The distance F between the focus O and the vertex S of the paraboloid P is called the focal distance of the mirror 1. It may be equal to

25   50 cm, for example.

The focal plane of the mirror 1 is the plane perpendicular to the Z'-Z axis which contains the focus O. A point in the focal plane is labeled by its

30   Cartesian coordinates along two axes denoted X'-X and Y'-Y. The X'-X and Y'-Y axes are mutually perpendicular and cut one another at the focus O.

The detection device comprises several detectors, also

35   used as sources of radiation in the case of a radar such as considered for this description. It may comprise for example four sources, referenced 2-5 in figure 1. The sources 2-5 are preferably all identical.

They may be of a type known to the person skilled in
the art. Each source 2-5 comprises a radiation
emission/detection cell and a frustoconical horn, or
collector. Each horn possess a determined cross
5   section, for example rectangular. The horn allows
impedance matching between the cell and the exterior of
the source.

Figure 2 is a view of the sources 2-5 in the focal
10   plane of the mirror 1. For the model of the sources
that is considered here, each source exhibits a
rectangular cross section in this plane. The wavelength
of the radiation is 31 millimeters, and corresponds to
a frequency of 10 GHz. The external dimensions of the
15   cross section of a source in the focal plane of the
mirror 1 may be, by way of example, 35 mm × 110 mm. The
sources 2-5 are disposed parallel to one another: their
principal direction of emission/reception is oriented
substantially towards the center of the mirror 1. The
20   small side of the cross section of each source 2-5 in
the focal plane is parallel to the X'-X axis and the
large side of the cross section of each source 2-5 in
the focal plane is parallel to the Y'-Y axis.

25   The sources 2-5 are disposed in the focal plane of the
mirror 1 in such a way as to be pairwise contiguous,
two contiguous sources being in contact along a part of
one of their respective large sides. Alternatively,
they may be disposed with an interval of separation
30   along the X'-X axis between two neighboring sources.

The sources 2-5 are furthermore offset with respect to
one another parallel to the Y'-Y axis, according to
respective offsets denoted d2-d5 in figure 2. Each
35   source 2-5 possesses a center of reference,
respectively denoted C2-C5, which is the focus of the
cell of this source. The foci C2-C5 are situated in the
focal plane of the mirror 1. The offsets d2-d5 are

respectively labeled with respect to the foci C2-C5, on the basis of the X'-X axis. Optionally, one of the sources (the source 4 in figure 2) is centered with respect to the focus O of the mirror 1: the

5   corresponding offset is zero.

According to the optical laws of reflection on the internal surface of the parabolic mirror 1, each of the sources 2-5 is then associated with a direction of

10   detection determined by the value of the offset of this source in the focal plane. More precisely, the focus Ci, for i = 2-5, is the center of convergence of a radiation Ri entering the mirror 1 along the direction of detection of the source i (see figure 1). In the

15   vocabulary of the person skilled in the art, the direction of detection of the radiation Ri is conjugate with the focus Ci of the source i.

By way of example of disposition of the sources in the

20   focal plane of the mirror 1, in accordance with figure 2, the foci C2-C5 are aligned along an oblique direction with respect to the two axes X'-X and Y'-Y.

A successive selection of each of the sources 2-5 makes

25   it possible to obtain a scan of the direction of detection of the device. This scan of the direction of detection possesses a component parallel to the Y'-Y axis. It consists of discrete jumps corresponding to the differences between the offsets of the successively

30   selected sources.

The selection of each of the sources 2-5 may be performed by means of a selection system corresponding to the diagram of figure 3.

35

Such a selection system 100 comprises two branches, or pathways, referenced V1 and V2. The pathways V1 and V2 are disposed in parallel between an input selector 101

and an output selector 107. An input of the selector 101 is connected to a general input for signals 110 via a high-power amplifier 112, denoted HPA. The selector 101 possesses two outputs connected respectively to the inputs of the pathways V1 and V2. A signal received at input by the selector 101 is reproduced on one or the other of its outputs as a function of a selection signal applied to a dedicated control input of the selector 101. An output of the selector 107 is connected to a general output for signals 111 via a signal limiter 113 and via a low-noise amplifier 114, denoted LNA. The selector 107 possesses two inputs connected respectively to the outputs of the pathways V1 and V2. A signal received by the selector 107 on one or other of its two inputs is reproduced on the single output of the selector 107 as a function of a selection signal applied to a dedicated control input of the selector 107.

Each of the sources 2-5 is linked to one or other of the pathways V1 or V2 by a respective selector 102-105. Each selector 102-105 possesses an input and an output that are connected to the corresponding pathway V1 or V2, and a two-way connection, or input/output, linked to the corresponding source. Each of the selectors 102-105 possesses three states selected as a function of a selection signal applied to a dedicated control input of this selector. In a first state, the selector reproduces directly on its output a signal received on its input. The other two states relate to the two-way connection of this selector: in the second state the selector reproduces on its two-way connection a signal received on its input, and in the third state the selector reproduces on its output a signal received on its two-way connection. The two-way connection therefore has a function of output of the selector in the second state, and a function of input of the selector in the third state.

The control signals for the selectors 101-105 and 107
are produced by a command unit 120 for the system 100,
denoted CTRL. The unit 120 is linked to the respective
5   control inputs of the selectors by dedicated control
links. The unit 120 is programmed to simultaneously
address appropriate control signals to all the
selectors 101-105 and 107. Thus, emission signals are
transmitted successively to each of the sources 2-5
10   from the amplifier 112, and reception signals arising
from each of the sources 2-5 are transmitted
successively to the limiter 113.

By way of example, during a detection performed by
15   means of the source 2, the selector 102 is firstly
controlled so as to be in its second state, and the
selector 101 is simultaneously controlled so as to
reproduce on its output connected to the pathway V1 the
signal received on its input. An emission signal
20   amplified by the amplifier 112 is thus transmitted to
the source 2.

A reception signal, associated with the previous
emission signal during radar operation, and originating
25   from the source 2 is thereafter transmitted to the
limiter 113 in the following manner: the selector 102
is controlled so as to be in its third state and the
selector 103 is controlled so as to be in its first
state. Simultaneously, the selector 107 is controlled
30   so as to reproduce on its output the signal received on
its input connected to the pathway V1.

The command unit 120 is programmed to periodically
repeat the control signals so that reception signals
35   originating from each of the sources 2-5 are
successively and cyclically transmitted to the limiter
113, to the amplifier 114 and to the output 111 of the
system 100.

Each of the selectors 102-105 causes an absorption of a signal that it transmits. For a selection system 100 in accordance with figure 3, a reception signal arising from the sources 2 or 4 undergoes an absorption by an

5   additional selector relative to a reception signal arising from the sources 3 or 5. Such an additional absorption may be compensated for, in a known manner, by an adaptation of the gain of the amplifier 114, said adaptation being controlled by the unit 120.

10

In a similar manner, the emission signals intended for each of the sources 2-5 undergo different absorptions within the selection system 100. These different absorptions may be compensated for by appropriate

15   adaptation of the gain of the amplifier 112, said adaptation being controlled by the control unit 120.

Figures 4 and 5 correspond respectively to figures 2 and 3, for a detection device such as described

20   previously, but incorporating five sources.

In accordance with figure 4, a fifth source, referenced 6, is added in the focal plane of the mirror 1, forward of the alignment of the sources 2-5, such as

25   illustrated in figure 2. The source 6 is contiguous with the source 5. The focus C6 of the source 6 is situated at the distance d6 from the X'-X axis: d6 is the offset of the source 6 in the focal plane of the mirror 1.

30

The selection system 100 comprises an additional selector, identical to the selectors 102-105 and referenced 106 (figure 5). The selector 106 is connected to the source 6 by its two-way connection,

35   and is connected at input and at output respectively to the connectors 104 and 105. The selector 106 can alternatively be connected to another location of the pathways V1 or V2. The programming of the control unit

120 is then adapted to take account of the additional source 6.

By iteration of such an addition of a source, it is
5 understood that the principle of the invention may be applied to any number of sources placed in the focal plane of the mirror 1. The selection system 100 must then be adapted accordingly, following a similar principle to that of the adaptation just described for
10 five sources.

Figure 6 illustrates the principle of selection of a single source to determine the direction of detection of the device, in the case of any number of sources
15 disposed in the focal plane of the mirror 1. The situation represented corresponds to the selection of the source 2 at a given instant, which is then activated (solid intermediate arrow), while the other sources 3-5, ... are not activated at this instant
20 (dashed intermediate arrows).

A use of a four-source radar in accordance with the invention is now described, which illustrates the implementation of a mode of detection of the ScanSar
25 type.

The detection device is installed onboard an earth observation satellite 10 (figure 7). The satellite 10 moves with a component of speed V parallel to the
30 surface of the earth. The azimuth direction, parallel to the component of speed V, is indicated in figure 7.

The direction of detection, oriented from the satellite 10 to the ground, is labeled in standard manner by the
35 angle of elevation, perpendicular to the azimuth direction. The ground trace resulting from a variation in the angle of elevation is also indicated in figure 7.

The satellite 10 is oriented so that the Z'-Z axis of
the detection device is substantially directed towards
the surface of the earth. It is moreover oriented so
5   that the X'-X axis of the detection device is parallel
to the azimuth direction. The Y'-Y offset axis of the
sources 2-5 in the focal plane of the mirror 1 is then
parallel to the ground trace of a variation in
elevation. Optionally, the orientation of the detection
10   device may be adjusted with respect to the satellite by
means of an appropriate orientation system ensuring the
link between the mirror 1 and the satellite 10.

When the satellite 10 moves, the detection device scans
15   a sweep S1 parallel to the azimuth direction. The use
of a detection device of SAR type makes it possible to
obtain, in a known manner, a high effective resolution
in the azimuth direction.

20   The selection of each of the sources 2-5 defines
juxtaposed sub-sweeps referenced S2-S5, the union of
which constitutes the sweep S1. The sub-sweeps S2-S5
correspond respectively to the sources 2-5 disposed in
the focal plane of the mirror 1. The distance between
25   central lines of two contiguous sub-sweeps is
determined by the difference between the offsets of the
corresponding sources in the focal plane of the mirror
1.

30   A scan B of the sweep S1 in zig-zag fashion is obtained
through a succession of detection exposures in each of
the sub-sweeps S2-S5. Each exposure corresponds to the
selection of one of the sources 2-5. When the control
unit 120 of the detection system 100 selects the
35   sources at a sufficiently high frequency with respect
to the component of speed V of the satellite, complete
coverage of the sweep S1 is obtained.

Figure 8a is a more exact diagram of the ground field
corresponding to successive exposures effected during
the scan B. The axes of the diagram of figure 8a
correspond respectively to the ground distances along
5   the elevation direction (abscissa axis) and the azimuth
direction (ordinate axis). Each field is elliptic, and
exhibits dimensions which depend on the shape of the
mirror 1 and the orientation of the mirror 1 with
respect to a horizontal plane parallel to the surface
10   of the ground. The ground fields are each limited by
concentric envelopes corresponding to constant values
of gain, respectively of -1dB, -3dB and -5dB with
respect to the reception gain maximum attained at the
center of each field. In figure 8a, each field is
15   labeled as a function of the sub-sweep S2-S5 to which
it belongs.

The diagram of figure 8b represents the variations of
the reception gain in the direction of elevation. It is
20   shown in correspondence with the diagram of figure 8a.
The abscissa axis of figure 8b is a projection of the
plane of figure 8a parallel to the azimuth direction.
The shape of the gain curve corresponds to cross
sections of each of the elliptic fields of figure 8a.
25   According to figures 8a and 8b, the width L of the
sweep S1 is around 40 kilometers and the width of each
of the sub-sweeps S2-S5 is around 10 kilometers.

By virtue of the respective offsets adopted for the
30   sources 2-5 in the focal plane of the mirror 1, along
the Y'-Y axis, the reception gain diagram of figure 8b
exhibits, between two successive maxima corresponding
respectively to one of the sources, a gain minimum of
less than around 1.0 dB at each of said maxima. The
35   sweep S1 is then covered in the elevation direction
with a quasi-uniform detection sensitivity: the various
sub-sweeps are contiguous, and no "dead band" of
detection exists between them. The exploration of the

geographical zone is then optimal in the elevation direction.

This exemplary use shows the benefit of a detection device according to the invention for performing a rapid exploration of a geographic zone with a minimum number of passes of the overflight machine above this zone. It is understood that numerous modifications of the detection device may be introduced with respect to the embodiments described. Such modifications remain within the framework of the invention, insofar as several detectors are placed in the focal plane of a single parabolic mirror, so as to cover sub-sweeps juxtaposed in a continuous manner elevation-wise.